THE INSTITUTE OF PHYSICS

47 BELGRAVE SQUARE, LONDON, S.W.1.

BULLETIN

No. 43 JULY, 1953

CONTENTS

THE IMPACT OF PHYSICS ON SCIENCE AND RELIGION - 75
By C. E. Raven

THE BOURNEMOUTH CONVENTION - - - - - 79

THE TEACHING OF FUNDAMENTALS - - - - 82
I—In the Schools. By G. R. Noakes
II—In the Universities. By J. G. Wilson

APPOINTMENTS VACANT : COURSES - - - - - 85

Information in this Bulletin is not intended for general publication: your copy should not therefore be passed to a library.

THE IMPACT OF PHYSICS ON SCIENCE AND RELIGION *

By Rev. C. E. RAVEN, D.D., D.Sc., F.B.A.

It is an ancient and not unseemly custom in assemblies such as this that the role originally played by the skeleton at the feast should be perpetuated by what our Latin ancestors called the *filius terræ*, the son of the soil, the bumpkin who could bring the experts to earth with crude homely comments upon their mysteries. You will remember that St. Paul when describing the sessions of those who spoke with tongues refers sympathetically to the *idiotes* who was present during their performances. This evening my part in your program is obviously that of the earth-born and earth-bound, the idiot, the amateur. Even in your most familiar utterances, the replacement of a simple word like universe by " multidimensional space-time continuum " transforms for me wonder into bewilderment : I cannot imagine, let alone describe, what you mean by it ; and when any of you explains it so that I understand, I feel tolerably sure that the explanation must be wrong. To invite me to address you is to put me in a position which demands your pity if not your contempt. You will, like the reviewer of my Gifford Lectures in your *Bulletin* be disappointed in me.

Nonetheless you *have* invited ; and perhaps there is some value in these days of intense specialisation in having one session of a Convention devoted to a view of its special studies from outside and at a distance. You carry too great a responsibility ; you are too deeply involved in researches of a tremendous if not of a suicidal sort, to be able to ignore the repercussions of your work. Perhaps one who used to play golf with Sir Joseph Thomson before the first world war, and listened to Lord Rutherford's prophecy of the time when atomic energy should banish drudgery and lift the whole level of human life, and who has received kindnesses beyond counting from two generations of scientists may be able to indicate some at least of the less obvious effects of your achievements.

Of the impact of physics upon science and religion (the subject of my discourse) there can obviously be no doubt. I do not believe and have done my best to disprove that science began with an apostolic succession from Copernicus or perhaps even Grosseteste to Newton : but that Newton, whether we condemn him with Blake as " like a hoar-frost and a mildew," or praise him with Wordsworth for " voyaging through strange seas of thought alone " by his *Principia* and his *Opticks* initiated the concept of a reign of law, validated the confidence in mathematics as the true discipline, and committed science to the use of quantitative categories and mechanistic analogies, no one will attempt to deny. His great generalisation not only drew world-wide attention to physical research, but in its consequences transformed man's way of life from rural to urban, from agricultural to industrial, and his way of thought from poetry to prose, from the organic to the mechanical. Science which had hitherto been chiefly concerned with medical and biological problems, with botany and zoology, had reached a point of development from which it could not proceed until the basic subjects, physics and chemistry, had been freed from the Aristotelian belief in the four elements, and from primitive confidence in magic, astrology and alchemy. After Newton the old age in which all things were possible, the age of Ariel and Oberon, of witches and the black boy, came to an end, and the ordered sequence of cause and effect proved itself in the subjugation of the powers of steam and high explosives and in the myriad developments of engine-room and factory. The amazing changes which have now affected every country in the world and altered man's whole concepts of space and time, of himself and of the universe spring out of the Newtonian physics. By the beginning of the present century they seemed to have established their universal validity : the whole cosmos appeared to be a closed system, of which an objective, exact and ultimately complete account, analysis and exposition would soon be available. Man himself was about to share the fate which Descartes had pronounced for all other living creatures : he was an automaton, explicable in terms of physics and chemistry ; and all his experiences, thoughts and aspirations would soon be formulated upon the analogy of a mechanical robot. That in my own undergraduate days such convictions were not openly expressed was due to the curious conspiracy of silence or gentlemen's agreement by

* Based on an address delivered at the Bournemouth Convention of the Institute.

which it was assumed that the two worlds of the ghost and of the machine were wholly separate and need never be brought into contact. Science dominated the machine ; religion must be content with the ghost. Science dealt with fact and the whole temporal realm ; religion was avowedly concerned only with the things of heaven. Mankind in A. D. Darbishire's phrase acclaimed the machine as " the darling of its adolescence and the symbol of its power." It only needed the behaviourism of Dr. J. B. Watson to complete the construction of a crudely materialistic philosophy. Those of us whose memories go back to the early years of the century cannot easily forget the tension and bewilderment of those days when as Gilbert Chesterton put it to E. C. Bentley :

" A cloud was on the minds of men and wailing went the weather,
" Yea a sick cloud upon the soul when we were boys together.
" Science announced nonentity and Art admired decay
" The world was old and ended but you and I were gay."

All honour to those valiant liberals who refused to regard themselves as chessmen.

It is peculiarly appropriate that as the origin of this disease came from physics so from physics should come its cure. None of us realised on the morning when our daily papers carried the head-line " Light on the bend " that this cryptic phrase was the evangel of a new age. Einstein was hardly known outside the circle of mathematical physicists ; and for the ordinary man the detailed arguments on which his theory was based were frankly incomprehensible. But even if the mathematical basis of relativity was too abstract for us, its challenge to the prevailing belief that quantitative science could give an objective and accurate three-dimensional picture was speedily appreciated. Einstein himself is no doubt right in insisting that in fact it was Clerk Maxwell and Heinrich Hertz who " demolished the faith in mechanics as the final basis of all physical thinking " but they were hardly conscious of what they had done ; and it was not until Einstein's own achievement that scientists and all of us except perhaps Mach had any idea that " the closed universe " was now open. Even then we were very slow to realise the full implications of what had happened. Its whole impact is scarcely yet realised.

It would be unnecessary in a company like this (even if I were competent for the task) to describe the steps by which the " new physics " developing from Einstein's work has revolutionized our concepts of the basic nature of the universe, and profoundly affected not only our whole approach towards particular physical problems but our fundamental attitude towards the relationship between experience and its interpretation. Suffice it to remind you that in place of the old picture of the three-dimensional world of space and time—a picture easily described and drawn on the black-board—we have now to deal with the unimaginable abstraction of a multi-dimensional space-time continuum, a subject for which only the formularies and equations of the highest kind of mathematics are appropriate ; that to-day according to Heisenberg a physicist if he would take into account all the phenomena with which his studies are concerned must employ four different basic hypotheses associated with the names of Newton, Riemann, Einstein and Planck ; and that now as in the seventeenth century there are two rival theories, wave mechanics and quantum mechanics, which seem irreconcilable except in terms of complementarity.

The general effect of these changes has been to shatter beyond recovery the rather complacent, indeed almost patronising, attitude of man towards the universe which the triumphant expansion of mechanistic interpretations had inevitably encouraged. Those of us who have spent a lifetime in questioning the omnicompetence of quantitative methods and the adequacy of the human intellect to act as a universal measuring-rod will share my experience of the radical change that has taken place. If scientists were before overconfident, they are now perhaps unduly sceptical ; if they seemed once to have banished mystery from nature, they have now recovered and reinstated it ; if at the beginning of the century it was believed that given a few more years of undistracted research mankind could not only " grasp this sorry scheme of things entire," but " remould it nearer to the heart's desire," there is now in every field of human endeavour a distrust of the sufficiency of the available techniques and a doubt whether any finality of definition is within our capacities.

It may be worth while to attempt a fuller description of the change in our outlook. Before 1905 we were inclined to regard man's experience of wonder and bewilderment, of encounter and frustration in his reaction to the universe as a hang-over from the primitive awe and fear of his ancestors : such experience might supply valuable material when it was shaped into concepts, and built up into hypotheses, and ultimately integrated into a coherent interpretation in terms logically consistent and practically useful : according to such ideas Linnaeus had been right in naming man *Homo sapiens* ; and man could renew his ancient claim to be " the measure of all things." With the coming of relativity this position was again reversed : it was realised that man's experience was in fact ultimately indefinable because no available technique, neither mathematics nor science, neither art nor music was capable of interpreting without scaling down and over-simplifying its character ; that the ancient belief that man's reach exceeded his grasp might be a truism but was also a truth ; and that as Wittgenstein has urged the ineffable though it cannot be stated in words can perhaps be shown in the quality of the integrated personality. In any case the belief that science could formulate a single all-inclusive and objective exposition of the whole realm of experience in terms of physics and chemistry was abandoned.

It is of interest, even though it is not wholly relevant, to note that a similar recognition of the inadequacy of traditional methods of presentation was beginning to find expression in the arts. Painting and poetry, sculpture and music were rebelling against the restrictions which had hitherto been almost universally accepted. Nor were the artists content to acknowledge the limitations of their techniques : they began the experiments which have now given us a long succession of movements, impressionism, cubism, surrealism and so on and have been widely though not very convincingly welcomed. Certainly, as is perhaps inevitable, these new pictures and poems throw more light on the moods and tenses of their authors than on the nature of reality. In spite of the eulogies of self-appointed claimants to " education and sensibility " they are often trivial, affected or pathological, yet the sense of freedom and of adventure which has encouraged them is already arousing fresh interest and may well lead in time to valuable developments.

These very significant changes in our basic approach to reality though accompanying and initiated by the new physics have drawn their influence and character from many other elements in man's reaction to his contemporary environment, both intellectual and practical. Of greater interest for our present purpose are the specific developments in particular fields of science which have emphasised and contributed to the revolution in our outlook. These constitute the contemporary

impact of the new physics upon science in general and may be roughly classed in their order of appearance and fall under four main heads.

There is first the change in the concept of natural law. It was the supreme achievement of the seventeenth century to replace the old picture of a chaotic world in which witches and demons, angels and " acts of God " might intervene at any moment by that of a world of law with its ordered sequence of cause and effect. By the end of the nineteenth century that picture had become universal : and the Mendelian laws of heredity as expounded by William Bateson seemed to fasten upon man himself a determinism more rigid than that of Calvin.[1] The laws of science were as the law of the Medes and Persians which altereth not ; an absolute rigidity conditioned man's whole nature physical, mental and moral. In such a world there was no room for freedom, responsibility or standards of good and evil ; in genetics there were no exceptions—or so we were constrained to believe. For one who like myself was researching at the same time in the heresy of Apollinarius of Laodicea and in the heredity of melanic mutants among lepidoptera the issue was one of profound importance. It was only after years of experiment and on the strength of a striking series of observations by A. Bacot and L. B. Prout and then of Udny Yule's statistical investigation of Biffen's work upon wheat that I realised that law was not in all cases universal and immutable. Even when this was proved, the modern definition of it as a summary of statistical averages came as an immense relief. The recognition that there is a constant but unpredictable element of variability in the whole order of nature transforms the cast-iron sequences of the old concept into a process in which change and creativity can and do occur. The difference between the two, as with relativity so here, may be quantitatively minute : it is philosophically immense.

The second change affects the scope of the field of scientific enquiry. We were brought up to believe that science must limit itself to the realm of weight and measurement, to the phenomena of sense-perception ; and that it was not concerned with the realm of values, of the imponderable and ineffable. Biology could only be accepted as within the proper category if with Descartes the organism was regarded as an automaton ; and in fact on these terms biologists did little more than dissect corpses in a laboratory. Psychology was for a long time refused recognition as a science ; it won a grudging admission when disguised under Dr. J. B. Watson's alias of behaviorism ; but when it became obvious that behaviorism was self-contradictory and absurd, there followed a long period in which the rigorists treated the subject as a branch of physiology if not of organic chemistry and refused to recognise any of the evidence which psycho-analytical and psychiatric researches were producing. When at last the evidence for the effects of what Dr. F. H. A. Marshall called exteroceptive stimuli[2] and what others defined in terms of the influence of mind upon matter began to be inescapable, and when problems of consciousness and intelligence forced themselves upon zoologists and the medical profession, unwilling acknowledgment was given to the conduct of animals in cages and mazes and before long of animals in their natural conditions and environment. But there was and still is no general acceptance of the conviction that science must sooner or later take the whole intelligible world into its purview unless it is prepared to abandon all the important problems and confine itself to superficialities and gadget-mongering. We must surely all be aware (whether or no we have learnt it from Professor Gilbert Ryle or from the development of psycho-somatic medicine by Dr. J. Russell Brain) that the familiar dualisms which have dominated man's commonsense since Adam and his philosophy since Descartes have now been seriously challenged, and that in this age of specialization we cannot expect to understand anything unless we also attempt to understand everything. For myself I have been convinced ever since 1926 that science if it were to be true to its task must claim nothing less than the *totum scibile* for its province. We cannot appreciate and interpret the flower in a crannied wall unless we bring to the task a coherent idea both of the universe and of our own nature. That this idea cannot be complete and may well be a somewhat remote approximation must not make us reject it. To do so is to surrender all claim to wisdom.

The third change, though it has been long foreshadowed by those who objected to the loose talk of randomness and the nonsense that concealed itself under the title pseudo-teleology, has only lately become widely accepted ; and even its recent advocates, when stating the evidence for design at all levels of study and particularly in organic evolution, think it proper to do so with apologies and to explain that they are not returning to the analogy of the watchmaker and the watch. Considering the age and intensity of the scientific phobias aroused by the barest suggestion of teleological explanations such hesitations are natural enough ; and indeed no one wants to return to the views of Archdeacon Paley. But for one who has studied Charles Darwin's answers to Asa Gray or even Dr. Julian Huxley's comments upon Bergson and has wrestled with the simultaneity of modification in the development of structure or of behaviour, it is a blessed relief from muddled thinking to turn to the recent insistence upon an element of organic design. Against the ordered sequence or the simultaneous appearance of changes affecting the total constitution of the entity, if these changes appeared at random, the odds would be astronomical ; nor if all be chance is there any means by which each combinations could be fixed and perpetuated. Yet such changes do in fact take place and establish themselves. To explain them some co-ordinating factors inherent in the very stuff of the entity must be at work : randomness becomes an inconceivable source for them ; as an explanation its use merely evades the issues and darkens counsel.

To these three elements in the new situation a fourth more directly due to the development of physics but less connected with science than with ethics and religion may be added. Those of us who had the honour of knowing Sir Joseph Thomson, Lord Rutherford, Sir Arthur Eddington and other pioneers in atomic research will be familiar with the extent to which their work was inspired by the conviction that if only the unlimited energy locked up in the atom could be released and controlled mankind could be freed from drudgery, from poverty and want, and from the failure of food and resources which threatened civilization. Nuclear fission could lift the whole material level of human existence and put at man's disposal the means to produce an earthly paradise. Such dreams, contributing as they did to the optimism and confidence of scientists, were largely responsible for the faith in salvation by science which won so large an allegiance from western folk. Such dreams for us who shared them are in tragic contrast with what happened at Hiroshima and with the age of fear and suppression, witch-hunting and spy-mania that has followed it. That the means of salvation should be cornered by terri-

[1] cf. his inaugural lecture at Cambridge *William Bateson naturalist* pp. 327-8.

[2] Croonian lecture, 1936.

fied governments, investigated behind iron-curtains of secrecy, and canalised into the stock-piling of instruments of racial suicide under the direct leadership of the supposedly most civilized and Christian nations is a hideous commentary upon our pursuit of false gods. The irony of the situation is intensified by the fact that it is only from the scientists that any attempt to protest against it has come—although with a few honourable exceptions their protest has stopped short of any effective action.

What impact are such changes liable to have upon our religious convictions ? Granted that they represent a revolution in the general outlook and temper of scientists can we estimate and describe the resultant effect upon religion ? In these days when we are all aware of the break-down of traditional systems and sanctions and of the consequent lack of moral and spiritual agreement such questions have not only an individual but a social and world-wide importance. It is plainly impossible in the time available to examine in detail the situation in regard to particular beliefs and practices. But it should not be difficult to set out and perhaps even to agree upon certain broad principles which recent physical and scientific developments have disclosed and which have profound significance for religion.

First as we have already seen the new physics and the resultant cosmology have recovered for us the sense of mystery. As our concepts of the scale of the universe—in both directions the very great and the very small—are stretched and broken and as we realize that our human capacities even when expanded by the record of cosmic rays or the revelations of the electronic microscope are totally unable to give us an adequate apprehension of reality we can experience what our ancestors found in the desert or under the stars an encounter with the ineffable which evokes in us the characteristic response of awe and fear, of exaltation and abasement. We are aware at once of our oneness with all that is and of our isolation and solitariness within it. We are caught up into what can only be called worship and at the same time stricken down with the consciousness of our selfhood and our shame. Modern man faced with what he can only call the " holy "—the Greeks called it Pan and the Jews " the great I am "—can still appreciate the ancient myth of Adam and Eve who hearing the Lord God walking in the garden in the cool of the day (" I'm very sure He walks in mine ") hid themselves for they knew that they were naked. We to-day cannot but feel something of the same paradox of rapture and of humility as we confront the ineffable.

Secondly we have gained in spite of this sense of our own limitations a fuller appreciation of the underlying unity of the universe and of the continuity of its processes. Religion has too often fostered the belief that the world of nature and history was irrelevant if not hostile—that the universe was merely the theatre on the stage of which the drama of man's destiny (Paradise lost and Paradise regained) was to be played. For us who take the scientific disclosures of our time seriously it is obvious that we cannot thus confine the divine presence and creativity to a tiny section of the universe, or fit God into the gaps that still remain otherwise unexplained or segregate the supernatural from the natural. We must see the whole from first to last as one continuous and developing adventure, the story of evolution reaching its present stage in the history of mankind—an adventure which may from our point of view be expressed in terms of the development of individuality and the promise of community, terms which St. Paul expresses when he writes of the whole creative process as incomplete, as pregnant and in pangs till " the children of God " be brought to birth. That in the story of the earth there has been real progress and the emergence of novelty ; that living organisms have increased the scope and quality of their responses and gained in sensitiveness and vitality till and after the appearance of man ; and that the extension of freedom of choice involves the liability of error and at a higher level the possibility of evil and of rebellion ; and that suffering is as the Greek proverb says the school of experience ; these are truisms which bear directly upon the formulation of religion. Such a view of the creative process is certainly compatible with the Christian concept of God as love rather than power or wisdom.

Thirdly if the story of nature and history is one and continuing, then it must be interpreted in terms that do justice to its present stage as well as to its origins. Science has taken physics and chemistry as its starting-point and used their data to explain the whole course of events. But if the record from atoms to man is one tale, then organic and personal categories must also be employed. We must judge and describe the process not only from its starting-point but from its goal, in terms not only of the atom or the amœba but of Christ and His saints. At the least we must abandon the mechanistic philosophies which derive from Descartes and adopt instead the organic of which his contemporary Ralph Cudworth was the pioneer. This will involve for religion a return to the type of evolutionary theology outlined by the great Greek Christian scholars Justin, Clement and Origen and restated by the Cambridge Platonists whose support contributed so much in the early days of the Royal Society to the amazing progress of science in Britain during the second half of the seventeenth century. It will also involve the rejection of the concept of God as the master-magician operating arbitrarily upon the world from without, and a radical change in the attitude to miracle.

Fourthly arising out of these last two contentions we shall be encouraged to claim that necessary as is the attempt to give precise intellectual formulation to our concepts of reality such formulation is nevertheless only one means among many for its interpretation ; and is by its very nature never wholly exact or satisfying. We may go on to urge that as these various techniques are only partial instruments of personality, the one perfect interpretation of the divine will be the person of the perfect Son of Man. He if he is to be found, will be for us as he was for St. Paul the " image of the invisible God." In him we shall recognize a manifestation, an unveiling, of the ineffable : in him we shall see the true character of power and of wisdom. That is good commonsense ; and it is also good New Testament teaching. If accepted, it has certain obvious corollaries—for example that any verbal definition being partial is liable to restatement : we may accept the person of Christ as for us men final and sufficient ; we cannot put any hypothesis, be it creed or scripture, on the same level. Any interpretation lower than the personal will be secondary and approximate, and infallibilities whether of dogma or pope will have to be abandoned.

In this connection you will perhaps forgive a personal confession. After taking my degree in Classics I began the study of Christian theology and of Mendelian genetics in the same term ; and have continued ever since to examine the interpretation of evolution and of the character of Christ side by side. For many years the two subjects seemed not only disconnected but in large measure contradictory. The great event of my intellectual life was the discovery that certain significant questions were common to both fields, and that it was possible to compare the two and illustrate each one by the other.

When further experiment demonstrated that the correspondence between the two was neither trivial nor accidental and when my friend and colleague Professor Oliver Quick argued that there were two unique means for appreciating reality, the physical universe and the person of Christ, I felt encouraged to suggest that to study a subject like the existence of evil or the problem of pain from the two standpoints was to get a stereoscopic vision of it. This of course should be the case if the Christian's valuation of Christ is admitted : but the habit of using the two side-by-side will at least prevent the common heresy of believing that the evidence of nature has no importance for religion.

And if any of you object that such a comparison is absurd since it is not *in pari materia*, I shall venture to reply that such an objection is no longer valid. In the facts of the physical universe as in the facts of the life and influence of Christ we are dealing with our own experience of them. The starry heavens above and the moral law within are, as my friend Professor Coulson has been showing, no longer to be regarded as so far separable as Kant supposed. We can no longer so easily distinguish the objective from the subjective : in the last resort the realm of the quantitative cannot be set in its obvious contrasts with the realm of the qualitative. One who realizes that both the moon above and the Church below are data given us in experience will not refuse to allow that the two have at least that much in common ; and as I compare the impact of the two upon me I find the ground for an easy contrast rapidly diminishing. A whole man will strive to appreciate and to benefit from whatever source of influence survives his critical scrutiny and commends itself to his æsthetic, intellectual and practical judgment. He must prove all things from the atom to the saint if he is to hold fast that which is good.

Finally if as all recent research seems to suggest the universe is much more " all of a piece " and nature much more intimately bound up with man than we used to suppose, then the new partnership between the various faculties and techniques of man including in particular the mutual understanding between science and religion becomes a matter not only of interest but of vital and urgent importance. Plainly if we are to surmount the insurmountable difficulties of our day we shall require every possible reinforcement of our efforts. Not only, in view of the scale and complexity of the issues, do we need a new degree of human co-operation, but we must by all means recover the secret of that creative fellowship which when it is manifested seems to make mankind free of the limitations that divide and sterilize him and to put almost limitless resources at the disposal of his community. Such fellowship will not only be our effective remedy against the disintegrative effects of over-specialization ; it will produce and make available a wealth of integrated and effective energy.

THE BOURNEMOUTH CONVENTION

About 450 members, ladies and guests attended the Institute Convention at Bournemouth from May 27 to 30 last. The general opinion appears to be that it was an outstanding success.

The Convention began and ended with excellent social functions ; the first was a civic reception at which guests were received by the Mayor and Mayoress of Bournemouth (Councillor H. P. E. Mears, O.B.E., J.P., and Mrs. Mears), and the President of the Institute, Dr. Sykes, and Mrs. Sykes. The second social function was a dance on the evening of the 30th at which the Mayor and Mayoress were guests of the Institute.

The two main scientific lectures were by Dr. A. C. Menzies, F.Inst.P. (" Recent developments in applied optics ") which will be published in the *Journal of Scientific Instruments* and Sir John Cockcroft, F.Inst.P. (" Recent advances in nuclear physics ") which will be published in the *British Journal of Applied Physics*. Dr. Menzies illustrated his lecture with many excellent demonstrations.

On the evening of the 28th Dr. C. E. Raven spoke to an audience of over 500 on " The impact of physics on science and religion." It was a most impressive occasion ; for more than an hour and a quarter Dr. Raven, speaking almost without notes, held his audience. What can be no more than the approximate text of the lecture is published in this issue of the *Bulletin*.

Other sessions of the Convention included the Annual General Meeting of the Institute (a report of which will appear in the August *Bulletin*), a discussion on the education of physicists and twelve Group meetings at which twenty-three papers were read. The two papers read at the Education Group meeting on " The teaching of fundamentals " are published in this *Bulletin*.

During the Convention five of the Groups held small dinner parties and one held a cocktail party. A cocktail party was also given by Mr. O. W. Humphreys, on behalf of the President, to graduate and student members and their ladies. Parties visited the de Havilland Aircraft Co. Ltd., the Signals Research and Development Establishment of the Ministry of Supply and the Admiralty Materials Laboratory ; five social outings were also arranged.

The permanent officers have received many letters expressing appreciation of the arrangements made at Bournemouth ; some useful suggestions for future Conventions have also been received. These they have been glad to have and they would welcome additional suggestions.

THE BOURNEMOUTH CONVENTION

The Mayor and Mayoress of Bournemouth and Dr. and Mrs. Sykes who received guests at the Civic Reception.

Mr. and Mrs. O. W. Humphreys with Rev. Dr. Charles E. Raven.

Sir John Cockcroft, Lady Cockcroft, Mrs. Allibone and Dr. T. E. Allibone.

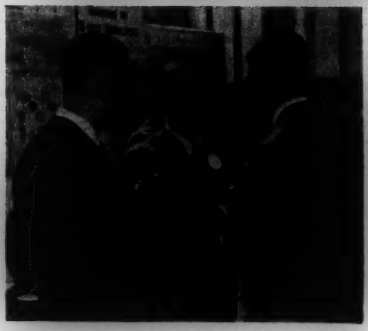
Right: Dr. A. C. Menzies giving the opening lecture.

Above: Professor N. F. Astbury, Dr. S. Whitehead and Professor S. Tolansky. Facing the camera, behind Professor Tolansky, is Dr. Ezer Griffiths.

Right: Mrs. Topping, Mr. E. van Someren, Dr. J. Topping, Dr. J. H. Fewkes and Mr. T. H. Tyler.

Above: Dr. D. H. Follett, Dr. B. P. Dudding and Professor A. M. Tyndall.

Right: Dr. J. Thewlis, Sir John Cockcroft and Professor F. A. Vick.



THE TEACHING OF FUNDAMENTALS *

I—IN THE SCHOOLS

By G. R. Noakes, M.A., F.Inst.P.

The passage of time brings little change in the aims and fundamental problems of physics teaching in schools, and the quality of our raw material in this generation must be very close to earlier specifications. Many of the points I should like to put before you for discussion this morning were made very forcibly as long ago as 1899 by that great and beloved teacher Professor John Perry, who began his book *Practical Mathematics* with the following words :—

> " The average boy receives no education at school except through his sports. He ought to be actively acquainted with concrete things before he is asked to reason about them. Quite early he ought to measure, weigh, and compute. A boy's main business at school is to continue the study of observational and experimental science which he began on the day he was born. He is taught many subjects in watertight compartments, whereas he ought to learn many subjects as if they were one.
>
> Again, we make two very great mistakes. We painfully impress on a child that an idea is difficult to understand, an idea perfectly familiar to it since it was three years of age. We assume that a child can understand quite readily some grown-up idea that to us is simple. Thus we produce stupefaction, and the child is mentally shipwrecked. It seizes upon any raft for safety, and the raft ever ready is a formula, a rule. If schoolmasters studied their pupils as trainers of animals do, they would find the average boy capable of the highest kinds of intellectual work.
>
> At present, one or more years of a student at a Technical College are wasted in trying to eradicate the evil produced at school, and in teaching him what he ought to have learned at school. Usually, however, it is too late. If every boy were made fond of reading he would educate himself during the whole of his life."

These words were written, of course, before the principle of Secondary Education was formulated by Balfour in 1902. But this, though generalised by Fisher (1917) and extended into a somewhat unwieldly Equation of State by Butler (1944), does not impinge on the real problems. For these are not matters of organization but involve chiefly the relations between teacher and pupil, the attitudes of each towards the subject and the kind of people they are. I do not agree perhaps with every word of Perry's. I think we schoolmasters do understand our pupils pretty well—at least to the extent of realising that they for their part study us as if we were performing animals, possibly fairly low in the scale of evolution; and we do try very hard to do a good job of work. But this quotation contains the kind of criticism which can still be levelled with some justice at our finished products, and also suggests some of the lines along which we are in fact striving.

The organization of the syllabus is much as Perry might have liked. The usual grammar school course in physics is to be found in the General Certificate regulations of any of the examining bodies. It is fair to say that this has not been dictated from above, but has crystallized in this form in the light of many years experience. The two levels "Ordinary" (O) and "Advanced" (A), with the dividing line at the age of about 16, are quite different in outlook. At O level the pupils are taught to observe, to measure, to build up a background of simple experimental facts, and to perform direct calculations related to the simple experiments encountered. At A level, the treatment is more theoretical, general principles emerge fully, and the pupil is led to see the subjects as a whole. While the outlook is still experimental rather than mathematical, he is expected to be able to do problems which call for the exercise of some reasoning and mathematical power. We don't of course encourage any " watertight compartments " point of view, but a boy has to master one thing at a time and must organize his facts on some sort of system, which is helped by taking together those observations which bear a fairly obvious relation to one another.

A glance at any examination syllabus suggests a formidable mass of work to cover in the time available. But, as mentioned in the Report discussed at last night's meeting, it is unusual for the teacher to attempt to cover all in the greatest detail. Certain parts, however, are really fundamental and should be done with the utmost thoroughness. We shall all surely agree about experimental mechanics. I would suggest that electrostatics and sound, which experience indicates are often neglected for various reasons, are also of prime importance.

The whole of the rest of physics is based on mechanics. The student must realise that this is the basic experimental science, the only means of real personal contact with the concepts of classical physics. Newton makes clear in his preface to the *Principia* the difference between " mechanics " (the principles involved in solving a problem) and " geometry," or as we should say now " applied mathematics " (the tricks that can be done mentally in using the result when we have got it). Both of course are important, but the mechanics must take precedence of the geometry. I have often found myself at cross-purposes with applied mathematics particularly when applied in the wrong place—the formula proudly displayed for substitution, the ingenious technique for solving a problem much more difficult than that actually set, and so on. I even feel at times that the whole is an artificial barrier set up to conceal the fact that the experimental principles are so few, and to screen the sensitive young from premature contact with the facts of life—that is, from the law of conservation of energy and the laws of motion. A boy cannot really understand any advanced level physics unless he has grasped experimentally the concepts of force, work energy and power. He must get his grounding in mechanics in the laboratory. Mechanics is not dull unless it is made so; it can, on the other hand be made most interesting, and even thrilling. I remember when I first started teaching using that famous book, Cox's *Mechanics*, the first half of which is devoted to a purely experimental and historical account of " the winning of the principles " before it gets down to a lively discussion of the application of these principles. I felt that this book made mechanics enjoyable, and it left this impression of the subject on the boys who worked through it.

Next, electrostatics. I have heard all the reasons for not trying to teach it. " The experiments don't work." " You can never get the apparatus dry." " The theory is too abstract." And so forth. Yet in electrostatics we have the main link between mechanics and the concepts of electricity

* A paper read at the Bournemouth Convention of the Institute.

and atomic physics—that of permanent magnetism has surely been severed in the light of modern knowledge.

Thirdly, sound. It seems that we often make a great deal of fuss over the wave theory of light, carefully ignoring the photon aspects, introducing ripple-tanks for qualitative explanation, and so on, yet never quite reaching the stage at which the propagation of electromagnetic waves or any other kind of waves is really intelligible. The teaching of wave-motion somehow fails to arouse interest if it is made incidental to the theory of elementary physical optics. But with sound, the waves and the vibrations are there themselves to be studied. Probably the chief barrier to sound in the past has been that the simpler experiments appeal chiefly to the musically-inclined boy, and that little time is available (after physical optics has misfired on wave-propagation) for the many beautiful more advanced sound demonstrations with strings and pipes and mechanical models which would carry the subject to a really fruitful stage.

The pupil who is going to the University to meet thermodynamics, electronics, and wave propagation (to mention only classical physics) will certainly be found wanting if his grounding in the work I have mentioned is insecure. But of course he may go with a good Advanced level pass and still know little of any of them.

A different point which might be taken up briefly for discussion if you wish is the impact of modern physics and modern ideas on the actual teaching. The picture is so much clearer now than it was when many of us were at school that it is possible to view the subject of physics as a whole, with a full awareness of general principles as they are now understood. There seems no more justification for excluding simple qualitative electron theory at the earliest stages than there is for trying to teach elementary chemistry without reference to the atomic theory. Is it wisest to introduce modern ideas incidentally from time to time as they are helpful, or should they be made topics to be taught fully for their own sakes ?

The physicist depends on instruments in his work but his basic instrument is himself. The older classical discipline did not aim merely at teaching Latin and Greek, but at developing a scholar's outlook towards men and life, at building a whole personality. It was by all accounts exacting, and the pupil was surrendered to it entirely. The modern scientific education will fail to develop the right type of man if it attempts to teach physics and chemistry, however efficiently, without creating an active scholar's outlook which is as full and balanced as that of the classic, but embraces the physical world without ignoring the world of men and affairs. It would be wrong to suggest that the full severity of the nineteenth-century discipline is necessary or desirable to-day but the willingness to work hard and to dedicate oneself to the purpose of becoming a true man of science certainly are. Many of the boys one teaches have all the necessary personal qualities in their make-up. But the prevailing climate of the world outside, where half-done work is the utility standard, and profitless distractions multiply from day to day, is one in which these gifts may well tarnish unless we battle vigorously to preserve them. Modern life, due very largely to the progress of physical science, has shed a good deal of its drudgery ; perhaps the only thing that has not been made easier is the self-discipline needed for the mastering of physics itself. It is even truer now than it was in the time of Archimedes that there is no royal road, but the trouble is that nowadays people are conditioned to expect one to be provided for them. The supply of physics teachers, in the schools is a matter of general concern, about which I need say nothing here, but of greater concern, I would suggest, is the shortage of real learners. In our teaching it would be as well to resist the temptation to teach too much. Instead, encourage the pupil to learn more for himself. Give the very minimum of help ; insist on him doing things on his own ; drive him, quite brutally if need be, to develop some initiative and self-reliance.

Outside the laboratory, one way in which we can carry on the fight is by the encouragement of some profitable constructive hobby. And another is by fostering a love of reading, as Professor Perry so wisely said. Reading with intelligence and concentration is a dying accomplishment in these days of browsing and skipping and headlines and comic strips. The educational ladder used to be a hard climb for the lad who is stuck to his books ; radio and television offer us a Jacob's ladder, a ladder of dreams for which literacy is a redundant preparation. I am not here descrying the immense value of both services in widening people's experience and implanting new and stimulating ideas. The standard of educational broadcasting is of course high, and the spoken word is reinforced by excellent publications, but I am thinking rather of the way it has displaced the habit of reading in leisure for pleasure, of using the gift of literacy for its own sake, and there can be no substitute for this. In a number of schools the need for reading is taken very seriously. For one or two periods a week, in school hours, the boys sit down in class for private reading—anything they care to choose, with a certain guidance of choice by the form-master, and simply reading for their own pleasure. Not all of them, of course, acquire what might be called a definite literary taste, though some reach a stage of real enthusiasm for certain authors. Not only is this practice felt to be a good thing in itself ; but with older boys, it is by way of keeping in training for the severer tasks ahead. For once a boy has grown to like reading good books, for his own entertainment, the habit of solid reading for study is likely to come naturally to him. He has become a reading man, and is on the way to becoming a well-read man, a full man, the kind of person who, notwithstanding any shortcomings of our more deliberate efforts on his behalf, can stand on his own feet when he goes on to the University.

" I do not think that on the great issues of our day there can be such a thing as a scientific point of view. I do not even believe that there ought to be." N. F. Mott.

THE TEACHING OF FUNDAMENTALS *
II — IN THE UNIVERSITIES

By Professor J. G. WILSON, M.A., Ph.D., F.Inst.P.

Listening this morning to Mr. Noakes, I found myself forcibly reminded of remarks by the Director of the London School of Economics, Sir Alexander Carr-Saunders, reported from the discussion on " Success and Failure at the University " at last year's Home Universities Conference. " In those schools," he said, " which somehow manage to save their sixth-form pupils from the ill-effects of the excessive requirements of performance at the General Certificate of Education, work is done which is far nearer the University ideal than at the University itself. Passage to a University may indeed mean retrogression in methods of work." I am going to suggest at the outset that, more often than not, any account of our stewardship which those of us working in Universities may give will make poor showing beside that of abler schoolmasters. It would be unworthy of us, moreover, to take any comfort from the knowledge that Mr. Noakes has been showing us an ideal of school practice, and that a majority of schools certainly fall far short of this standard.

I can save time by noting that the general considerations we have just listened to apply as clearly in the University, through all teaching levels, as they do to the top forms in schools, and I'll go straight on to discuss some points of detail. These are largely based on my own post-war experience up to a year ago, at Manchester, where a great many unobtrusive but thoroughly discussed experiments in method and aims were tried out. I shall put my points as bluntly as I can, and hope that the other side of the argument will come up in the discussion. I'll confine myself, too, to physics specialists, not at all because the general or ordinary student does not set us problems, but because their problems are in many ways more difficult and raise issues far removed from the broad purpose of our discussion to-day.

Let me remind you that nowadays quite a considerable proportion of students graduating with honours go on to a further training period, either in a University (their own or another) or elsewhere, which is usually described by the all-embracing term " research." Whether the term " research " can properly be applied in a particular instance or not, what is notable is that the method of education changes most abruptly at this point, and the more conservative the undergraduate course has been, the more drastic is the change. One is driven to enquire whether what is so good for these fortunate people who continue their training for 5 or 6 years might not have been produced a little earlier for the benefit of those who go out of range of deliberate training at the time of their first degree.

The Universities are free from the restricting influence of an external examination syllabus ; in other words, they are confronted with the whole mass of developments in physics in the past, and their professional job is to produce the practitioners of the next generation. It would be convenient if these people went out first-rate mathematicians, able linguists, competent engineers, gifted electronic designers well informed on the whole range of physics, fundamental and applied, but it is far easier to admit the futility of such an ideal as a practical aim than to set down specific considerations to guide our choice of emphasis.

I think that the initial step is to recognize that physics, at least to the same extent as chemistry, geology, medicine, English and engineering, covers so much ground that some measure of undergraduate specialization is necessary. This may follow lines of aptitude, and it is now generally accepted that the man of promise in theoretical physics should cover different ground from the experimentally inclined, at least in his last undergraduate year, while a third-year electrical engineering option at Manchester has been strikingly successful ; or it may be based on interest, leading to a less sharp demarcation but allowing restricted topics to be studied to a detail where the way in which physics really develops can be appreciated. Only by such specialization can the active, thought-provoking aspect of physics be brought out from the mass of facts, laws, formulæ and such " stuff to be learnt " that will otherwise accumulate in the course.

Moreover, and I think this is quite crucial, a reduction of the level at which broad understanding of the subject is required has the further merit of emphasizing the less extensive, but *really essential* basis, of the subject, lack of which, we can all agree, marks serious deficiency in any so-called physicist.

There may be others here of my generation who will have vivid recollections of the caustic comments of Dr. G. F. C. Searle when the confident Part II student in the full swim of quantum numbers, spin, and wave functions, showed some hesitation in defining the specific heat of water, but now we seem to have grown uncommonly delicate about such matters, and it has become a breach of taste to ask anything so fundamental that failure has to be taken seriously. The habit is far too widespread nowadays of dismissing most of this essential matter as " too elementary " to be tested in a final examination, quite certainly encouraging many undergraduates to achieve a half-understanding of advanced topics (which they quite correctly assume will form the greater part of their examination), bolstered up by memorized formulæ which, with any luck, will remain in their minds until they are safely out of the examination room.

We will all agree, I think, about the central position which mechanics must hold in any system of physics, and I suspect that most of us have from time to time come up against the difficulties which arise in fitting mathematics into its due position relative to physics.

Perhaps I can say a word or two first about mathematics. There is a certain mathematical content in all effective physics which I think everybody here could accept, of which an important and typical addition at University level is wave propagation, in the first place on a directly mechanical plane and later in a broader context. I would suggest that the real essential in this instance is confined to plane waves : if the principles of motion of plane waves is really understood, extensions to less elementary wave problems, such as dipole radiation and so on, can be understood when they are encountered. The virtue of these mathematically more complicated systems does not, for the majority of physicists, reside in *being known* but in being appreciated as reasonable extensions from actively used generalizations. Of course, the student who is at all good will come across many of these more advanced mathematical formulations of which some are not amenable to further simplification. These will often arise in his specialization and here they assist in sharpening the precision of his ideas in a way which is wholly good. But what we have actively to discourage is the miserable memorization of " proofs " and formulæ which is no part of the

* A paper read at the Bournemouth Convention of the Institute.

students persisting understanding of physics, but which is deplorably effective as an examination technique.

We all know that while some activities of physics indeed demand high mathematical competence, many physicists do work of distinction with only modest calls on mathematical methods (anybody who doubts this may profitably read through the published work of recent British Nobel Prizemen), and we must not hazard the supply of physicists by demanding indiscriminately a high level of mathematical attainment both from those to whom it is a natural approach and from those who will certainly be driven to sacrifice something much more important to find the time and energy to master it.

When we turn to the constructive problem of stating what should form the basic elements of a university physics course, I have in mind particularly the man who has not got any strong mathematical bent. There is no great difficulty in providing drill for the budding mathematical physicist, but it has long been assumed that the experimentalist will acquire his skill by instinct. This assumption was all very well in the aptly-named string and sealing-wax era, when the most advanced skills invoked in the laboratory might be mastered by most people after a few days practice. The situation is radically changed now, however, and we have to recognize a twofold programme for these people :

(i) the presentation of the foundations of physics on very general lines—conservation of energy, laws of motion—co-ordinating the classical divisions of physics through the application of these foundations to an atomic model of matter and leading to a further general principle in quantization as it shows up throughout the various aspects of this model, and to the concepts of statistical assemblies as the necessary step to microscopic physics ; and

(ii) the development of a highly versatile technological skill, based on a deliberate study of the principles of observation and experiment, of instrument design and of the possibilities of available techniques.

Regarding the first, I need only say that there is scope for very varied approaches and for a good deal of experiment ; the essential point at issue at present is that of broad presentation, whether the co-ordination of phenomena takes place late in the course after a detailed study of the classical divisions (which always seems to involve overburdening each stage with trivial matters) or whether we build as I have indicated on a framework co-ordinated at the earliest possible moment. This alternative is attractive, although it has not yet been seriously attempted to my knowledge. At the least it merits critical examination, in which the extent to which it would upset cherished lecture syllabuses should not be an important factor.

I am clear that the technological training of the experimental student is not now adequately met by the scope of ordinarily available laboratory classes, and that the laboratory training must be supplemented by a substantial lecture course on the theory of experiments, of instrument design and of technical methods. In the Manchester post-war developments such a course has been recognized as outstandingly successful by staff and students alike. At the exploratory stage it was only possible because there was a member of staff specially qualified by knowledge and enthusiasm to make the experiment, but the more extended introduction of such courses should not present great difficulty. It is no alternative at all to expect modern good practice and technical method to be taken in as by-products of the general run of lecture courses.

I have not left myself time to underline, had it needed it, what Mr. Noakes said about application and hard work. I don't think that many of us are guilty of making physics appear an easy option but I am afraid it can easily be made to appear a dull option. We should keep before our own eyes and those of our students that in the world they will be judged by what they do, not by what they know, and that at the university level we will fail culpably if our physics students do not have positive encouragement to think for themselves and work and plan work for themselves. If, to do this, they must give up the struggle to cover all physics, however thinly, then I have no doubt what the correct decision will be.

NOTICE TO MEMBERS

Graduateship Examination 1953

The Institute's Graduateship examination was held from June 22 to 26 in London (the Institute's House) Wigan, (Mining and Technical College), Rotherham (College of Technology) and Paisley (Technical College). The examiners were :—

Professor F. A. Vick	(Physics I—General Physics and Acoustics ; Physics III—Electricity and Magnetism).
Professor A. M. Tyndall	(Physics II—Heat and Optics, More Advanced Physics).
Dr. J. Topping	(Mathematics, Mathematical Physics).
Mr. A. E. de Barr	(Electronics, X-rays, Temperature Measurement, High Vacuum Technology).
Mr. N. Clarke	(General Education).

Copies of the thirteen papers are now available from the Institute at 3s. the set. Copies of the 1952 papers are also available at the same price.

APPOINTMENTS VACANT

The inclusion of particulars of a vacancy must not be taken to imply that the Institute necessarily approves of the terms offered or that might be offered. Candidates should satisfy themselves that these are satisfactory, and they may always refer to the Institute for advice.

National Institute for Research in Dairying (University of Reading). Assistant Experimental Officer with sound theoretical and practical knowledge of electronic and controlling instruments required for duties in Physics Department. Candidates should preferably be graduates with a pronounced bent for instrument mechanics. Commencing salary within the scale £336 p.a. (age 21) to £576, with superannuation. Applications, with the names of two referees, should be sent to the Secretary, N.I.R.D., Shinfield, near Reading, by July 25, 1953. *Quote reference 53/9.*

Physicist, aged 25–30, with interest in engineering techniques required to carry out experimental and development work on research projects in rubber physics. Applications in writing quoting reference J.M. 17, to the Personnel Manager, **Dunlop Rubber Co. Ltd.,** Fort Dunlop, Erdington, Birmingham 24.

University of Hong Kong invite applications for the vacant post of **Senior Lecturer in Physics,** a post occasioned by expansion of the present establishment. Emoluments (for a married member of the staff normally resident outside Hong Kong or China ; and inclusive of allowances) : £1575–£40–£1735 p.a.

First-class sea passages and furnished accommodation at reasonable rentals are provided to expatriate staff.

Further particulars and information as to the method of application may be obtained from the Secretary, Association of Universities of the British Commonwealth, 5 Gordon Square, London, W.C.1. Closing date for the receipt of applications is 15th July, 1953.

Mount Vernon Hospital and Radium Institute, Northwood, Middlesex. **Physicist** (Honours graduate) required to assist in problems related to the treatment of cancer by X-Rays, Radium and Telecobalt with opportunities for research work. Previous experience of medical physics is desirable but not essential. Recruitment will be at a point within the Basic Grade of the National Health Service depending upon qualifications and previous experience, i.e., £460–£765, plus London Weighting. Applications, with the names of two referees, to be forwarded by 25th July, 1953, to the Secretary and House Governor.

South West Metropolitan Hospital Region. The Mental Hospitals' Group Laboratory, **West Park Hospital, Epsom, Surrey. Graduate Research Worker** with good honours degree (Physics, or Chemistry or Bio-chemistry with good Physics) required for the investigation of problems of blood viscosity. The post is temporary but affords an opportunity for exploratory work with a new technique. Salary (range £410—£735 plus London weighting) according to experience. Conditions as defined in P.T.A. Circular No. 9 of the Whitley Councils for the Health Services. Apply with two up-to-date references to the Group Pathologist at the above address.

Young **Physicists** with knowledge of Electronics required by firm of Consultants to join geophysical oil prospecting parties overseas. Commencing salary £600 p.a. Free messing and quarters provided whilst overseas plus allowances depending upon area of operations. Applications for higher positions are also invited from experienced geophysicists. Apply Box A.V.41. The Institute of Physics, 47 Belgrave Square, London, S.W.1.

Imperial Chemical Industries Limited, Billingham Division, has a few vacancies for physicists as **Assistant Technical Officers** in the Research Department. Initially the work will be in the field of optical spectroscopy, X-ray and electron diffraction, radio chemistry, and would be concerned with the operation of specialised apparatus. Candidates should have at least the Inter-B.Sc. qualification and a degree is preferable. They should be under 30 years of age. Write for an application form to the Staff Manager, Imperial Chemical Industries Limited, Billingham Division, Billingham, Co. Durham, quoting reference No. D.2.

A large glass **works** in the North East of England require a **Physicist** for their Research Department. Applicants should have a good honours degree or equivalent qualification. Good opportunities exist for a research worker of initiative and ability. The post is pensionable. Applications should be forwarded to Box A.V.42. The Institute of Physics, 47 Belgrave Square, London, S.W.1.

Physicist or **Graduate** of equivalent standing with experience of Optical Projection Instruments and Surface Analyser who wishes to enter business, wanted to take over sale of high-class instruments. Excellent prospects, eventually leading to managership of a department for right applicant. Applications should be addressed to **Gaston E. Marbaix Ltd.,** Devonshire House, Vicarage Crescent, London, S.W.11.

A **Physicist** who has recently graduated is required for research and development work on electro-magnetic problems in relation to aircraft instrumentation. Salary according to qualifications. Applications, stating age and details of qualifications should be addressed to Personnel Manager, **Louis Newmark Ltd.,** Prefect Works, Stafford Road, Croydon.

National Coal Board invite applications for a superannuable appointment at the Central Research Establishment, Isleworth, Middx. Candidates should have good laboratory experience in experimental Physics for work in ventilation and heat transfer. A pass degree or National Certificate in Applied Physics is desirable. Age not less than 25. Appointment will be either as **Scientific Technical Officer Grade II** (Salary £485 × £20 to £705 per annum) (male) or **Scientific Technical Officer Grade III** (Salary £375 × £20 to £535 per annum) (male) according to age and experience, plus London Location Allowance.

Write giving full particulars (in chronological order) of age, education, qualifications and experience (with dates) to National Coal Board, Establishments (Personnel), Hobart House, Grosvenor Place, S.W.1, marking envelope TT/645. Original testimonials should **not** be forwarded. Closing date July 27, 1953.

The University College of Khartoum, Sudan. Applications are invited for appointment to a **Lectureship** or **Assistant Lectureship in physics.** Salary on scale : Lecturer £E 1150 × 75 — 1525 p.a. ; Assistant Lecturer £E 950 — 1000 — 1075 p.a. Status and point of entry in scale according to qualification and experience. Cost of living allowance at present £E 144 p.a. Outfit allowance £50 on first appointment. Paid passages for member of staff and assisted passages for family on appointment, termination and leave (each long vacation after the first). No income tax payable at present in the Sudan. £E = £1 0s. 6d.

Applications (eight copies), giving full details of qualifications and experience and the names of three referees should be sent to the Secretary, Inter-University Council for Higher Education in the Colonies, 1 Gordon Square, London, W.C.1, from whom further information may be obtained. Closing date July 31, 1953.

COURSES

CITY OF BIRMINGHAM EDUCATION COMMITTEE
COLLEGE OF TECHNOLOGY
Birmingham 1
Department of Physics and Mathematics

Full-time and Part-time Courses for the B.Sc. (General and Special) degrees of the University of London, Graduateship of The Institute of Physics and National Certificates in Applied Physics. Several Post-graduate Courses in Applied Physics will be run next session. Further particulars from the Head of the Department.

THE POLYTECHNIC, REGENT STREET, W.1.
Department of Mathematics and Physics.

Full-time and evening courses for Inter-mediate, B.Sc. General and B.Sc. Special External Degrees of London University in Physics and Grad.Inst.P. Evening courses in Statistics, Electronics, Advanced Mathematics for Special Degree and post-graduate studies.

Prospectus available from the Director of Education.

MEMBER'S ANNOUNCEMENT

WANTED. London D.Sc. secondhand cap, hood and gown for medium height. Please reply to Dr. W. W. Barkas, College of Technology, Manchester 1.

F. J. MILNER & SONS LTD PRINTERS BRENTFORD · MIDDLESEX